DiFX Correlation & Fringe Search

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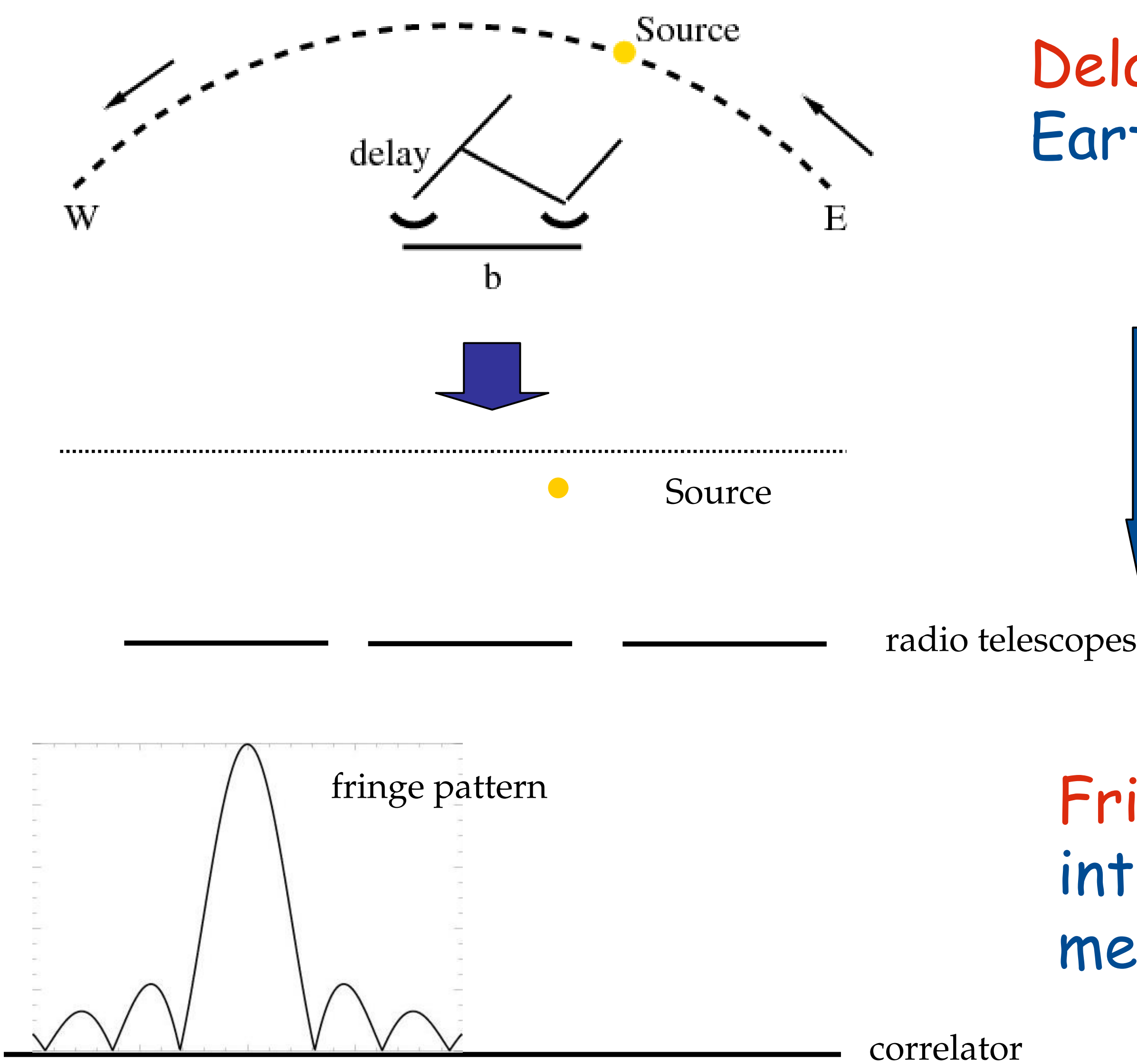
What Do We Measure & How ?



Delay (τ) changes due to Earth rotation.

A way to measure the delay is to cross-correlate the signal. (I.e. multiply and integrate)

Fringe pattern of the interferometer (VLBI measurable).

There is more than one way to develop a correlator to convert from time stream to cross-power spectrum:

- Lag correlator XF architecture (as the Mark IV)
- FX architecture (as the DiFX)

… and there is more than way to build one:

- Hardware (as the Mark IV)
- Hybrid (FPGA based – Allen Telescope Array)
- Software (as the DiFX)

DiFX

- DiFX -> Distributed FX correlator.
- DiFX is a software correlator.
- DiFX is a free downloadable software from:

http://cira.ivec.org/dokuwiki/doku.php/difx/installation

- DiFX needs IPP libraries (IPP requires licence).

DiFX is software running on various computer clusters. Every cluster performance is different, but...

the fundamental operations performed by the correlator are the same.

DiFX: receives digitized signals

applies the correlator model

pads the data from 2 bits to 16 bits

aligns the data within +/- 1 sample

performs an FFT

performs a fractional-sample delay correction

performs a complex multiplication & integrates

writes the complex visibilities (in freq. domain)

What correlators need:

1) Vex file (generated by the scheduler).
2) FS log files from the stations.
3) Modules or e-transferred data.
4) Mails from stations with comments for the observation.

What DiFX needs extra:

1) `v2d` file to convert the vex into DiFX-readable (ascii) files (generated at the correlator).

DiFX: Vex Files

Vex files are used by the correlators for:

- Sky Frequency → relevant for fringe rotator
- LO tuning → relevant for fringe rotator
- Recording speed → relevant for playback speed
- Polarization → relevant for channel assignment
- No. of BBCs → relevant for channel assignment
- Sources to be observed → coordinates for corr. model
- Length of the scans → relevant for playback
- Track assignment → relevant for channel assignment
- Antenna coordinates (not required for observing)

Correlator's vex files need extra information:

- Earth orientation parameters (x-wobble, y-wobble and UT1)
- Clock information (gps-fmout from field system logs)
- Data source (Mark 5 module, files on RAID)

Correlator's vex files need (sometimes) to be changed:

Track assignment (only tape-like tracks are present in vex)

Log files are used by correlators for:

- Clocks: gps-fmout values
- vsi4 = astro / geo
- Lots of useful info in case debugging is required:
  - LO tuning,
  - BBC/VC frequencies,
  - polarization,
  - track assignment - if Mark 5A
  - [....]

In this exercise we are using EUR122.

EUR122 is part of bi-monthly experiments dedicated to measure intra-European plate stability and tectonically induced strain accumulation.

It is a dual band (8 GHz and 2 GHz) experiment.

One polarization (RCP).

One bit sampling.

Observed on 20th March 2013.

24 h long, but only few scans of for these exercises.

DiFX: Login

Log in to: corr02

user/pwd as written on the board.

Change directory to /data-sc01/difxoper/eur122_n (where _n is the group nr that you are in)

In the directories there are the vex files and the FS logs and other ancilliary files required for correlation..

Task 1: Get familiar with the vex file.

Vex is divided into sections. All sections have a $SECTION (i.e. $MODE, $STATION $SCHED, $CLOCK….)

Within a section there are definitions that point to other sections:

```
$STATION
   def Ft;
       ref $ANTENNA = FORTLEZA;
   enddef;
```

DiFX: Vex File - Get Familiar

```
$MODE;
def GEOSX-SX;
ref $FREQ = GEOSX-SX01:Ft:Hh:Ke:Ny:Ts:Wz:Yg;
ref $BBC = GEOSX-SX01:Ft:Hh:Ke:Ny:Ts:Wz:Yg;
ref $IF = GEOSX-SX01:Ft:Hh:Ke:Ny:Wz:Yg;
ref $TRACKS = Mk34121-SX01:Ft:Wz;
ref $TRACKS = Mark5B:Hh:Ke:Kk:Ny:Tc:Yg;
$PHASE_CAL_DETECT = Standard:Ft:Hh:Ke:Kk:Ny:Wz;
[..]
enddef;
```

DiFX: Vex File - Get Familiar

```
$STATION
def Ny;
ref $SITE = NYALES20;
ref $ANTENNA = NYALES20;
enddef;
$ANTENNA
def NYALES20;
antenna_diam = 20.00 m;
axis_type = az : el;
axis_offset = 0.51980 m;
antenna_motion = az : 120.0 deg/min : 9 sec;
antenna_motion = el : 120.0 deg/min : 9 sec;
enddef;
```

DiFX: Vex File - Get Familiar

```
$FREQ
def GEOSX-SX01;
chan_def = &X : 8212.99 MHz : U : 8.000 MHz : &CH01 : &BBC01 :&U_cal;
chan_def = &X : 8212.99 MHz : L : 8.000 MHz : &CH02 : &BBC01 :&U_cal;
chan_def = &X : 8252.99 MHz : U : 8.000 MHz : &CH03 : &BBC02 :&U_cal;
chan_def = &X : 8352.99 MHz : U : 8.000 MHz : &CH04 : &BBC03 :&U_cal;
chan_def = &X : 8512.99 MHz : U : 8.000 MHz : &CH05 : &BBC04 :&U_cal;
chan_def = &X : 8732.99 MHz : U : 8.000 MHz : &CH06 : &BBC05 :&U_cal;
chan_def = &X : 8852.99 MHz : U : 8.000 MHz : &CH07 : &BBC06 :&U_cal;
chan_def = &X : 8912.99 MHz : U : 8.000 MHz : &CH08 : &BBC07 :&U_cal;
chan_def = &X : 8932.99 MHz : U : 8.000 MHz : &CH09 : &BBC08 :&U_cal;
chan_def = &X : 8932.99 MHz : L : 8.000 MHz : &CH10 : &BBC08 :&U_cal;
chan_def = &S : 2225.99 MHz : U : 8.000 MHz : &CH11 : &BBC09 :&U_cal;
chan_def = &S : 2245.99 MHz : U : 8.000 MHz : &CH12 : &BBC10 :&U_cal;
chan_def = &S : 2265.99 MHz : U : 8.000 MHz : &CH13 : &BBC11 :&U_cal;
chan_def = &S : 2295.99 MHz : U : 8.000 MHz : &CH14 : &BBC12 :&U_cal;
chan_def = &S : 2345.99 MHz : U : 8.000 MHz : &CH15 : &BBC13 :&U_cal;
chan_def = &S : 2365.99 MHz : U : 8.000 MHz : &CH16 : &BBC14 :&U_cal;
sample_rate = 16.0 Ms/sec;
enddef;
```

Task 2: Insert the EOP in the vex file.

Run the program `geteop.pl -h` (follow instructions). It creates a file called EOP.txt

DiFX needs to have 5 values of EOP and two of them must be prior to the observation start.

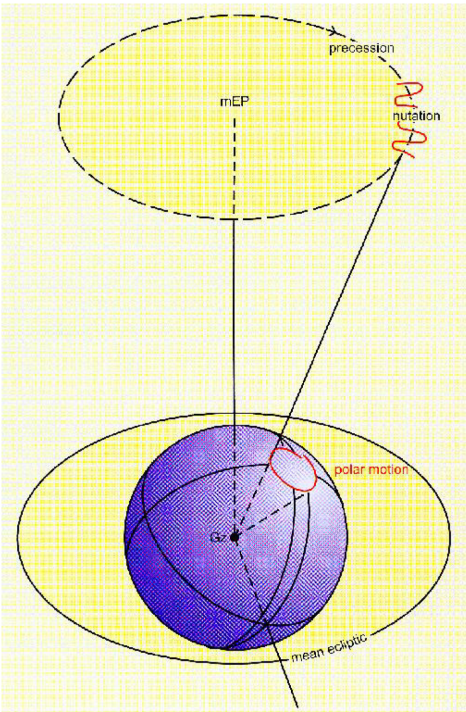
Insert the file EOP.txt in the VEX (no special position as long as it does not "break a $SECTION or is within a def / enddef).

E.g. if observation starts at Day of the Year (DOY) 100, then geteop needs as start DOY 98.

DOY of r1572 is found in $SCHED section in the scan name (e.g. 100-1700 => DOY-HHMM).

DiFX EOPs: geteop.pl

Earth Orientation Parameters (x-wobble, y-wobble and UT1).



DiFX ancilliary program `geteop.pl` reads the USNO file, reformats it and creates a file called EOP.txt

The predicted EOPs values are published from USNO:
`http://128.183.20.176/solve_save/usno_finals.erp`

EOP: VEX example for observation on DOY 035.

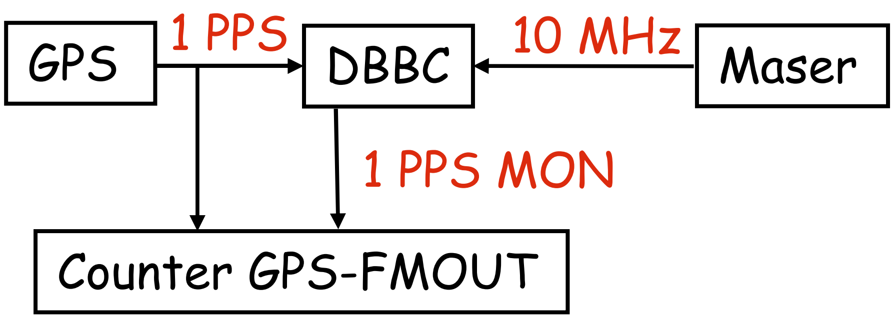
```
$EOP;
 def EOP0;
  TAI-UTC= 35 sec;
  A1-TAI= 0 sec;
  eop_ref_epoch=2013y033d;
  num_eop_points=1;
  eop_interval=24 hr;
  ut1-utc  = 0.237134 sec;
  x_wobble = 0.042530 asec;
  y_wobble = 0.313450 asec;
 enddef;
def EOP4;
    […]
 enddef;
```

Note: DiFX needs EOPs for 5 days of which two prior to the observation !

DiFX: Vex File - Clock

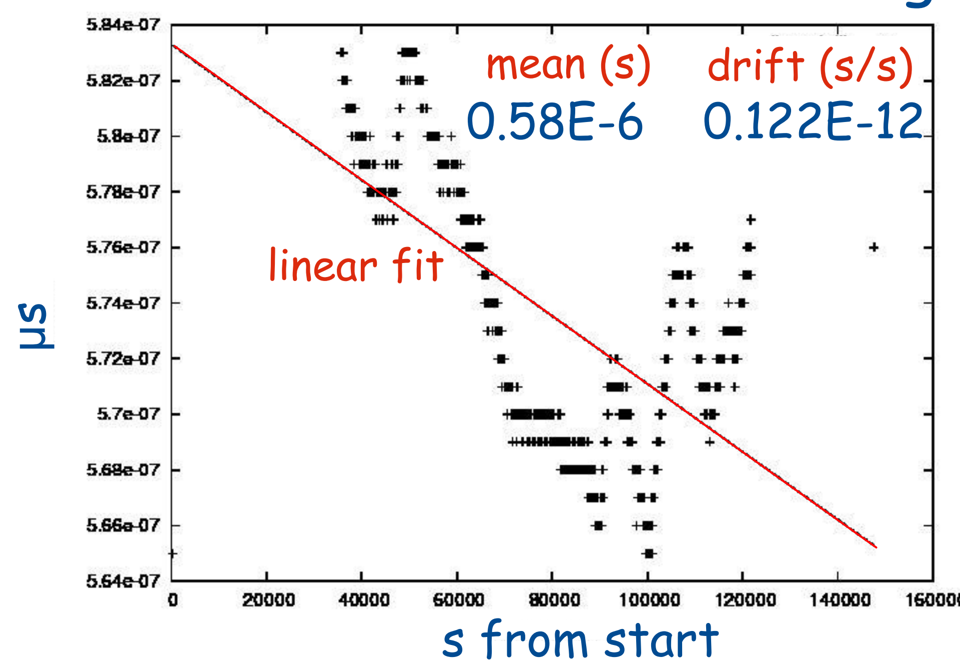
igg universitätbonn

CLOCK: estimates the time difference between the data time stamps (from formatter/M5B/ FiLa 10G) and UTC coming from GPS.



But 10 MHz drifts

GPS-FMOUT from FS log

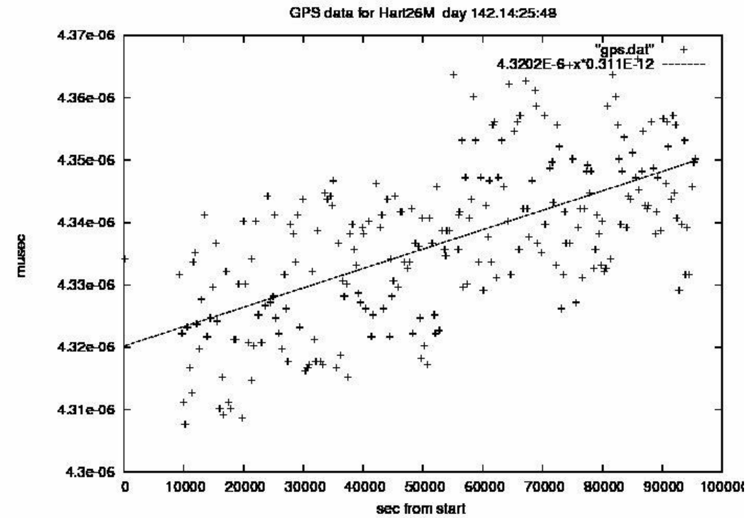


We use a program to calculate clock offset and clock drift from the FS logs and are written in the file clock.txt.

The program extracts the gps – fmout values calculates the mean (clock offset) and performs a linear fit to calculate the drift.

It creates also a postscript file with the fit.

e.g. clkm4 r1578on.log



Task 3: Clock offset and rate correction in the vex

```
$CLOCK;
def Ny;
 clock_early=2012y142d17h00m : X usec :2012y142d17h00m0s : x ;
enddef;
def Wz;
clock_early=2012y142d17h00m : Y usec :2012y142d17h00m0s : y;
enddef;
[…]
```

The X and Y µs are the mean gps-fmout "*clock*" values.

The x and y s/s are the clock drifts.

Check "track" assignment: vex speaks (still) tape language!

Mk 4	VSI=geo	VSI=astro	Mk 4	VSI=geo	VSI=astro
1US	0	0	1LS	16	16
1UM	1	1	1LM	17	17
2US	2	2	2LS	-	18
2UM	3	3	2LM	-	19
3US	4	4	3LS	-	20
3UM	5	5	3LM	-	21
4US	6	6	4LS	-	22
4UM	7	7	4LM	-	23
5US	8	8	5LS	-	24
5UM	9	9	5LM	-	25
6US	10	10	6LS	-	26
6UM	11	11	6LM	-	27
7US	12	12	7LS	-	28
7UM	13	13	7LM	-	29
8US	14	14	8LS	18	30
8UM	15	15	8LM	19	31

Check "track" assignment: vex speaks (still) tape language!

Mk 4	VSI=geo	VSI=astro
9US	21	-
9UM	22	-
10US	23	-
10UM	24	-
11US	25	-
12UM	26	-
12US	27	-
13UM	28	-
13US	29	-
14UM	30	-
14US	31	-

In vex enter VSI output + 2 !

i.e. 1US: VSI output = 0 → vex tracks = 0 + 2 = 2

TRACKS sorting in vex:

```
$FREQ;
def GEOSX-SX01;
chan_def = &X:8212.99 MHz:U:8.000 MHz:&CH01:&BBC01:&U_cal;
[..]
enddef;
[..]
$TRACK;
def Mark5B;
fanout_def = A : &CH01 : sign : 1 : 02 ;
[..]
enddef;
```

USB

From tables above:

Mk 4	VSI=geo	VSI=astro
1US (BBC01)	0	0

VSI output = 0, i.e. TRACK = 02

DiFX requires different files, based on vex .
The program `vex2difx` creates those files:

Input file:
- clock,
- frequency,
- tracks,
- integration time,
- baseline to cross-correlate …

Calc file:
- station coord.,
- EOPs,
- antenna mounting type,
- source coord. ….

Calc file $\xrightarrow{\text{calcif2}}$ Im file (Interferometer Model, i.e. correlator model)

More info:
http://cira.ivec.org/dokuwiki/doku.php/difx/vex2difx

`vex2difx` requires a `v2d` file.

Layout of v2d file:

vex = vex file name

antennas = two letter code of the participating stations
(e.g. antennas = WF, ON, WZ …)

singleScan = True/False

suggested value for trial-correlation

SETUP r1600
{
tInt = integration time in second (e.g. 0.2 s, 1 s …)
doPolar = True/False
nChan = no. spectral channels (e.g. 128, 512, 1024.., 2^{16})
}

Layout of v2d file cont.:

```
RULE clock {
    scan = scan name (e.g. 222-1700)
    setup = r1600
}
ANTENNA AB
{
 file = /path/scan name
}
```

In trial-correlation mostly only one scan

Task 5: Run the program vex2difx

e.g.: `vex2difx eur122.v2d`
vex2difx creates the files .input, .calc, ...

Task 6: Run errormon2

open a new window and type `errormon2` => error monitor

Task 7: Run the correlator

using the script `startdifx` :

```
startdifx eur122_1.input
```

Startdifx runs:

- `calcif2 -a` → to create the im file
- `genmachines <input file>` -> to create the machines and thread files
- `mpirun -np nn -machinefile <machine file> mpifxcorr <input f>`

no. of process to start
(found using wc -l machine file)

created from vd2

Run DiFX: Machine File

The machine file looks like this:

```
fxmanager 0 0
mark5fx01 0 1
[..]
Mark5fxnn 0 1
node55 7 0
node56 7 0
[..]
nodenn 7 0
```

- fxmanager 0 0 → Control the operation
- mark5fx01 … Mark5fxnn → Mark 5 Units available (1)
- node55 … nodenn → Compute nodes available (0)
- 7 → no. of cores used

eur122_1.machines

```
fxmanager slots=1 max-slots=1
node41 slots=1 max-slots=2
node42 slots=1 max-slots=2
[..]
```

eur122_1.threads

```
NUMBER OF CORES:    10
7
7
[..]
```

DiFX creates a directory called `eur122_1.difx` (DiFX visibilities and pcal files) and a file `eur122_1.difxlog` (errormon output).

Task 8: create the files for fourfit

`difx2mark4 eur122_1.difx` (will create a directory 1234)

Task 9: search for fringes

run `fourfit`: > cd 1234

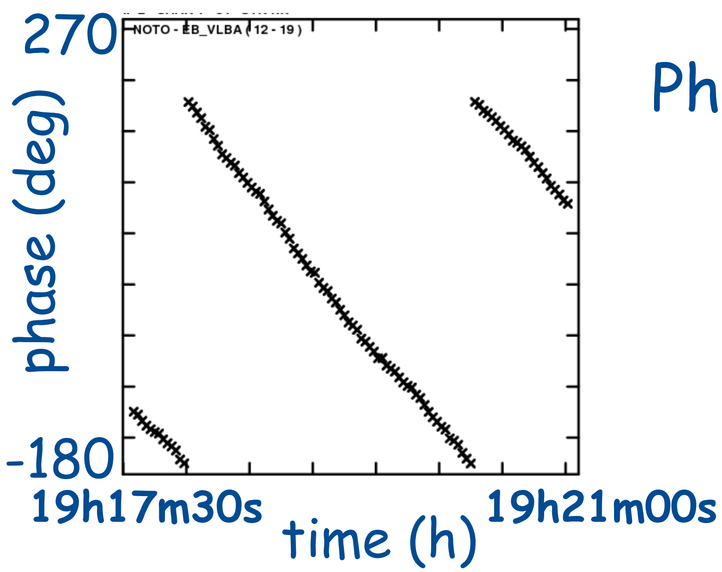
> HOPS (to set env variables for fourfit)

> fourfit -pt -c ../cf_1234 scan name

e.g. fourfit -pt -c cf_1234 056-1700

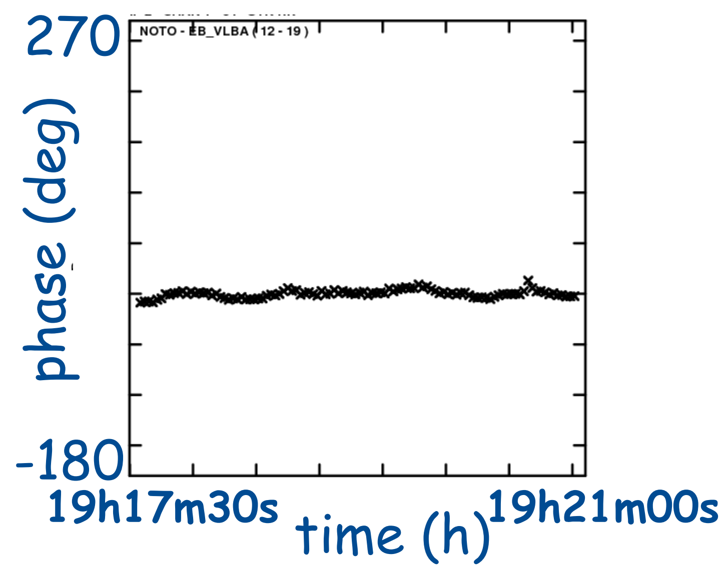
Why Fringe Fitting?

Due to errors in the model, the correlator phases still show a slope vs time:

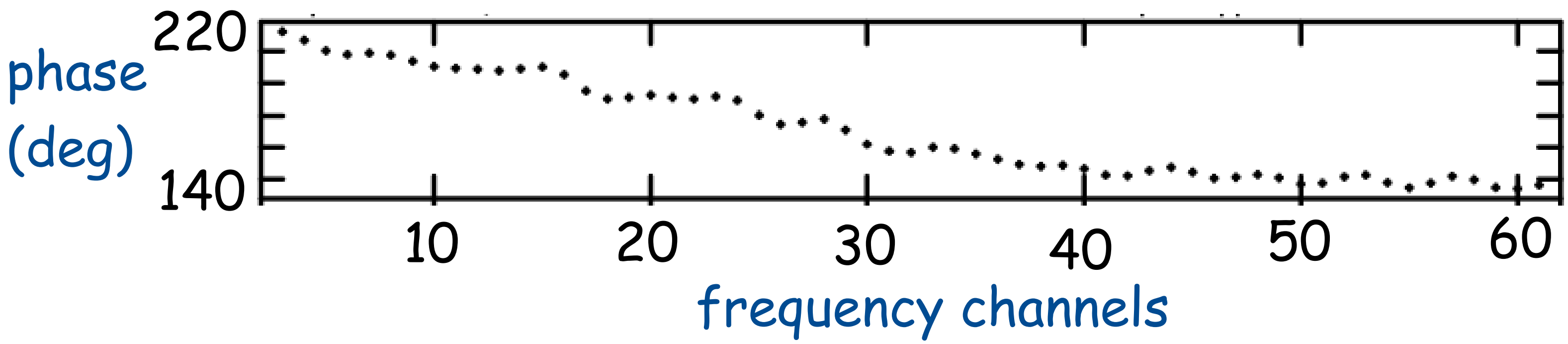


Phase slope vs time is "fringe rate"

Fringe Fit refines the model removing the fringe rate

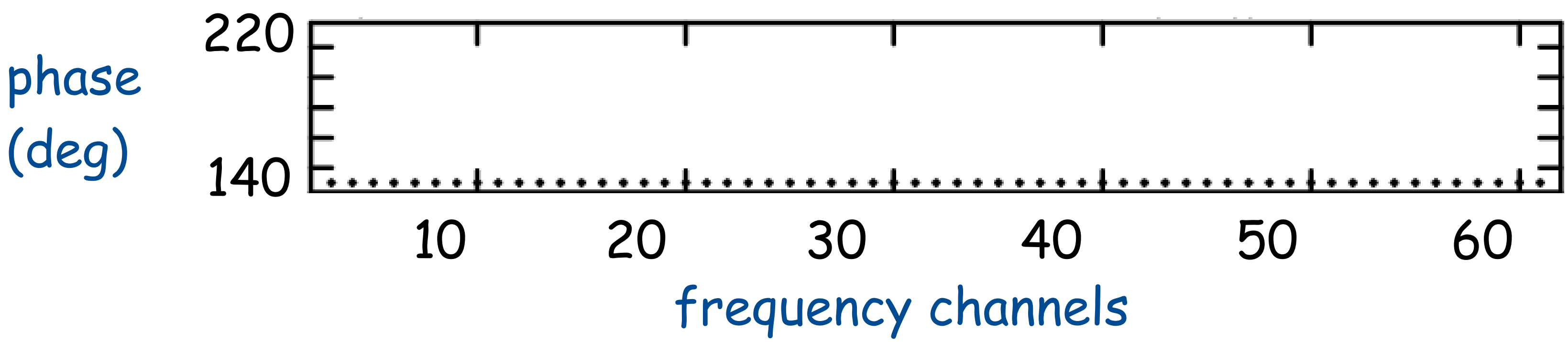


Due to errors in the model, the correlator phases still show a slope vs frequency:



Phase slope in frequency is delay.

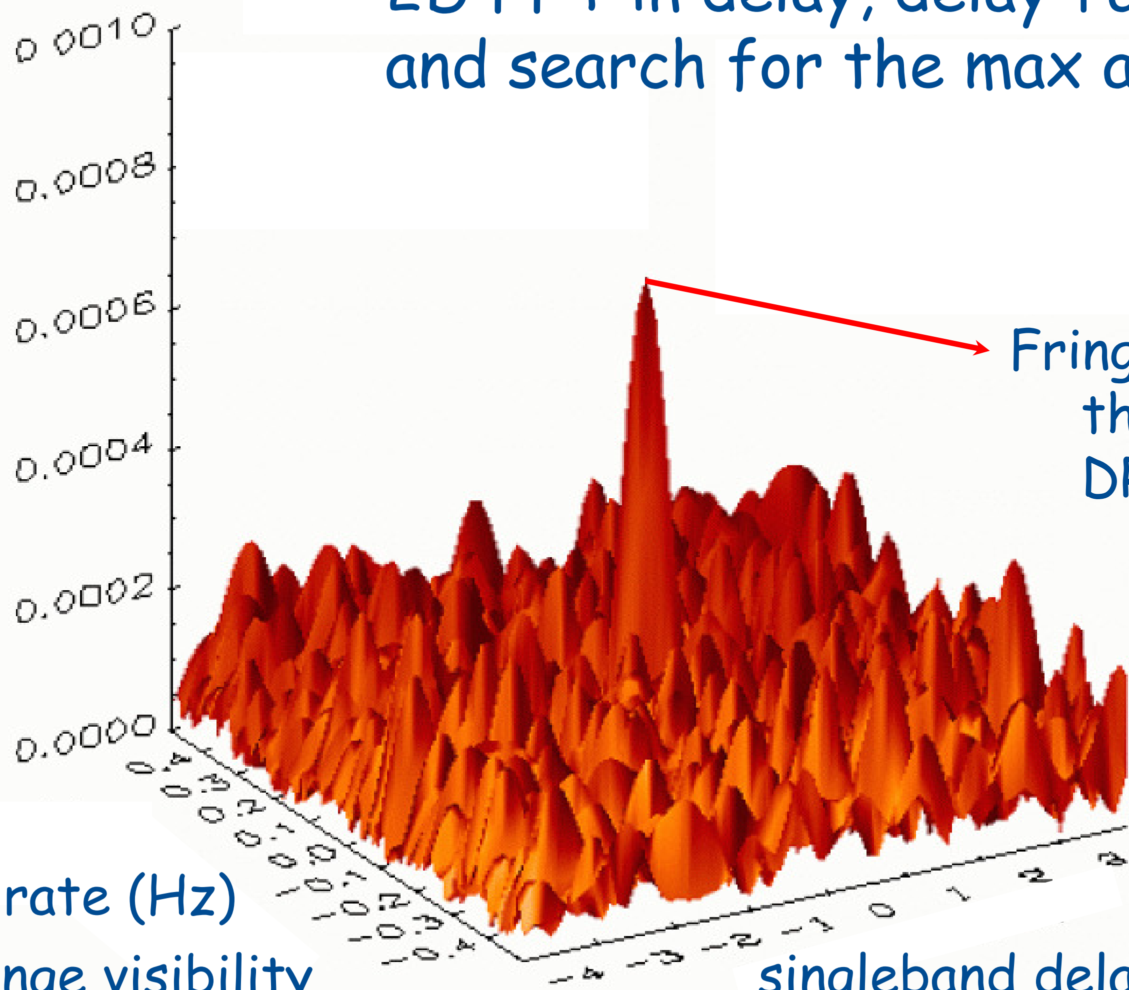
Fringe Fit corrects the delay pivoting around a reference frequency



Fringe Fit: Real Fringe Search

2D FFT in delay, delay-rate space and search for the max amplitude

Corr. amplitude



Fringes are located at this position in SBD, DR space

Fringe rate (Hz)

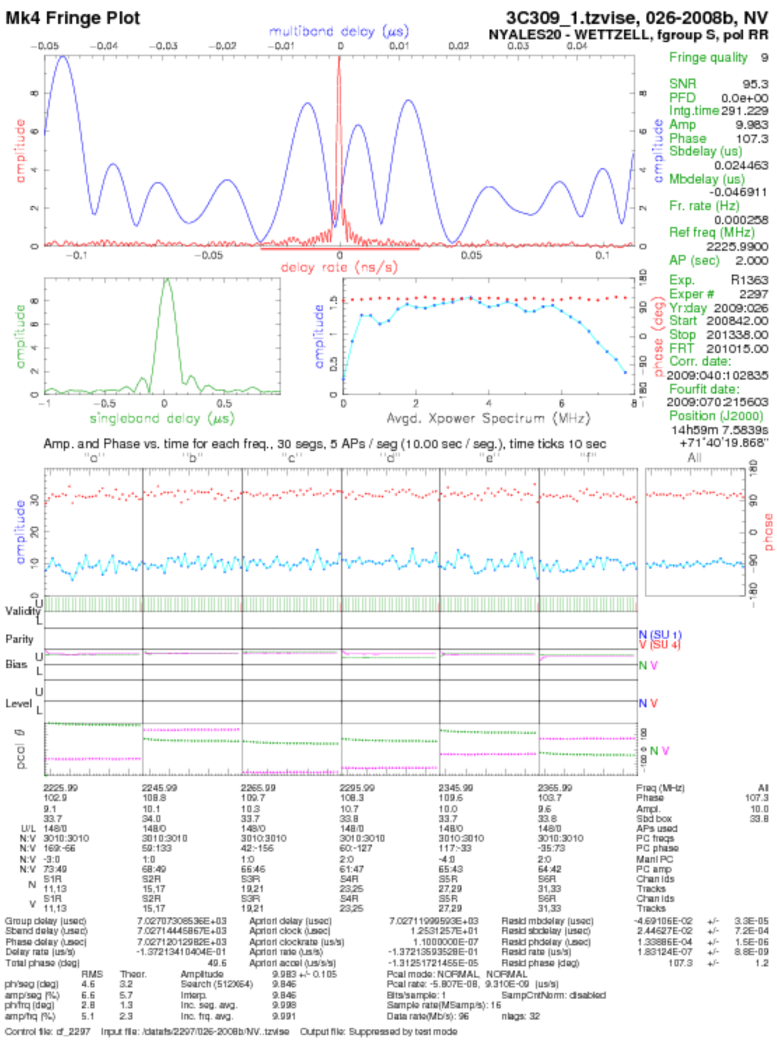
(FT fringe visibility with respect to time)

singleband delay (μs)

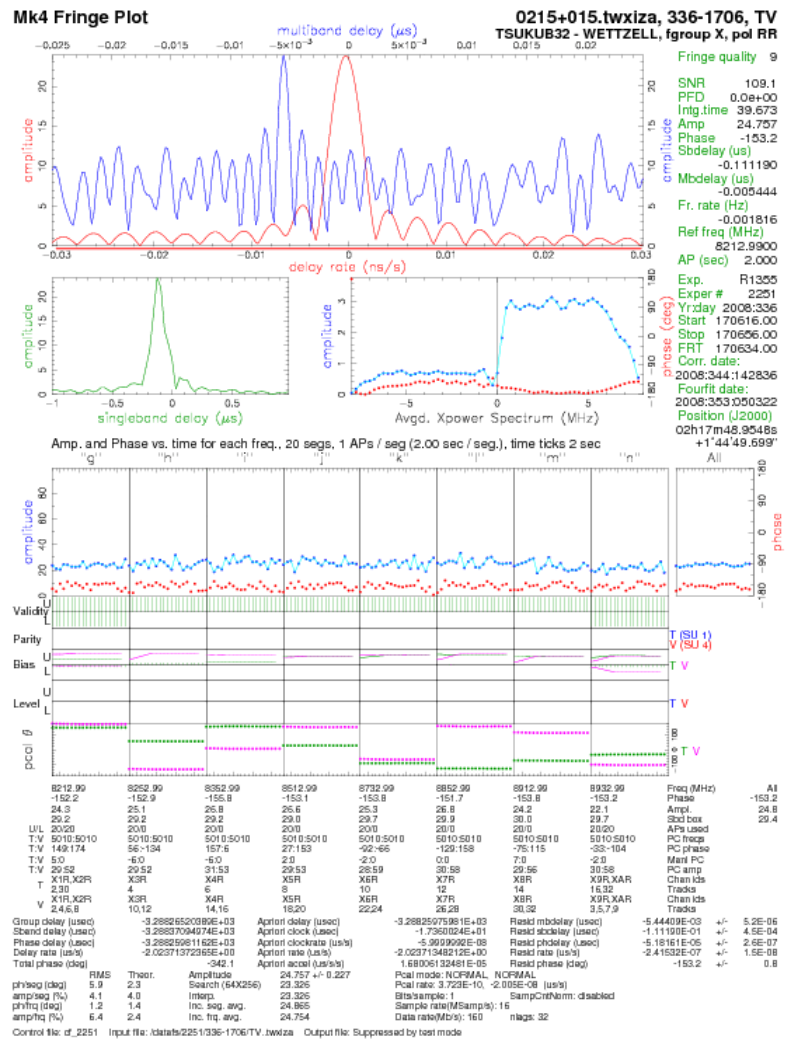
Image: Roger Cappallo

Fringe Fit: *Fourfit* Overview

S-Band:



X-Band:



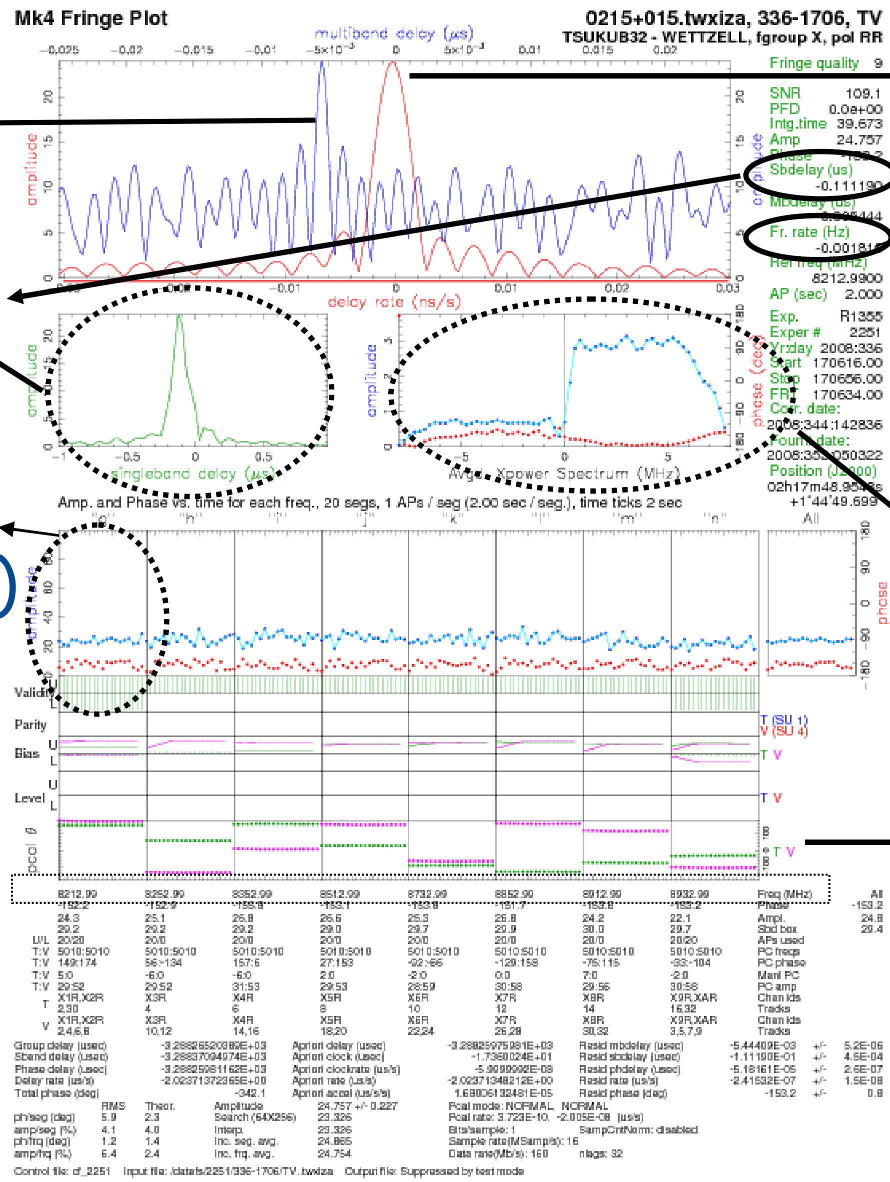
Fourfit

Multiband delay (µs)

Single band delay (µs)

Phase (red) & amp (blue) vs time for every BBC

Sky freq.



Delay rate.

Fringe rate (Hz) = Delay Rate • Sky freq.

FT of lag spectrum

Pcal phases

SBD ≠0 => non modelled station-based errors. But we can correct them!

<u>Task 10:</u> Change the clock_early entry in the vex file.

SBD is baseline-based => take one of the two station as reference and correct the other.

Suppose we have baseline *AB*

Suppose SBD = 0.6 µs on baseline *AB*.

Suppose clock_early *A* = 1.5 µs and clock_early B = -3.0 µs

If *A* is chosen to be the reference station =>

clock_early B = -3.0 + 0.6 = -2.4 µs

If B is reference => clock_early *A* = 1.5 - 0.6 = 0.9 µs

We have changed the clock model. Need to check it.

Remove the old *.input, calc, im, difx files

Re-run vex2difx – startdifx – difx2mark4 – fourfit.

Task 11: Is the SBD better?

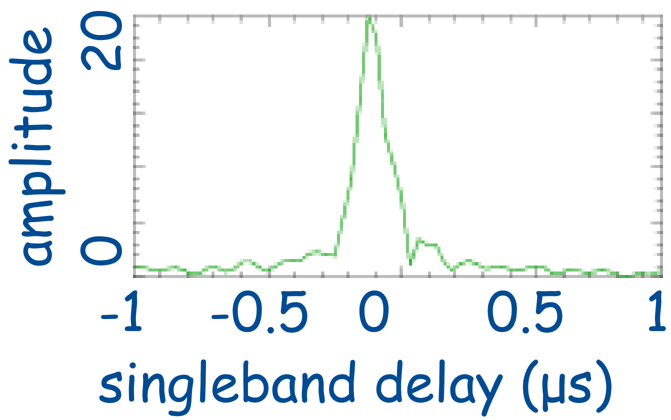
Now we break things!

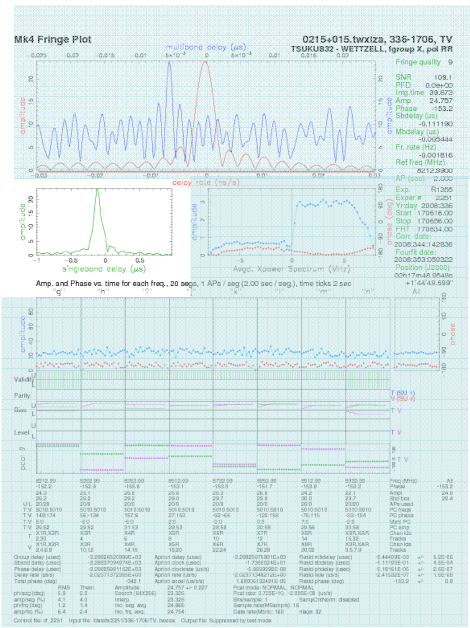
Task 12: Change the clock model at random: first only few µs, then of, e.g. 1 s.

Run the correlation and look at the data with fourfit.

What happens?

Fringe Fit: Singleband Delay (SBD)





- Lag spectrum: output of the correlator integrated over the scan duration.
- Lag spectrum shown is lag spectra of all BBC stacked.
- 8 MHz/BBC => 16 Ms/s =>
  sample period = 1 / 16 Ms/s = 0.0625 μs =>
  0.0625 μs * 32 lags = 2 μs SBD window width.
- Indicates residual correlator model errors, part of which can be absorbed in the clock offset.

Singleband Delay Errors

- Often: resetting of the formatter.
- Sometimes: gps-fmout values not reported either in the FS logs or in the ivs-ops messages.
- Rare: bad gps-fmout values reported in the logs.

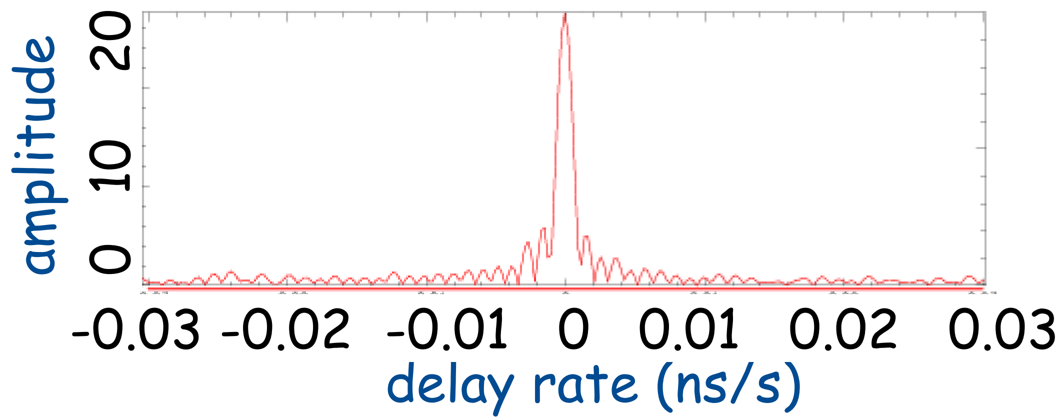
Cures?

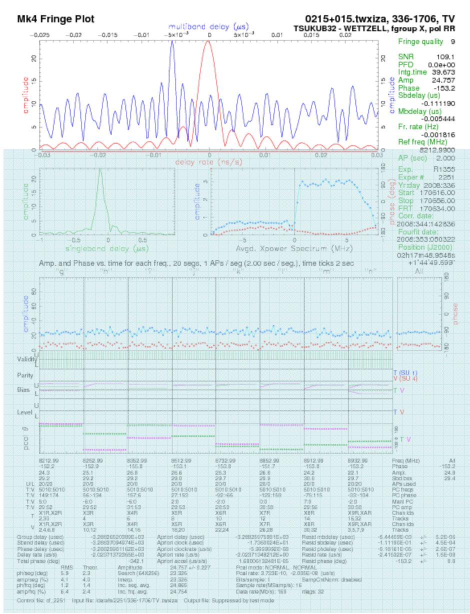
- Curable: gps –fmout not reported, bad counter reading (we use an old value to start with).
- Painful: resetting of the formatter.

Task 13: Increase the clock drift, or station coordinates, first only few m, then > 100 km.

Run the correlation and look at the data with fourfit. What happens?

Fringe Fit: Fringe Rate & Delay Rate





- Fringe rate is the Fourier transform of fringe visibility with respect to time.
- Delay Rate = FR / Observing frequency.
- DR window = [1 /(2 * AP)] / Obs. Freq.
- DR tells how fast the fringes move away from the phase centre due to correlator model error. It can be absorbed in the clock rate.

Fringe Rate Errors

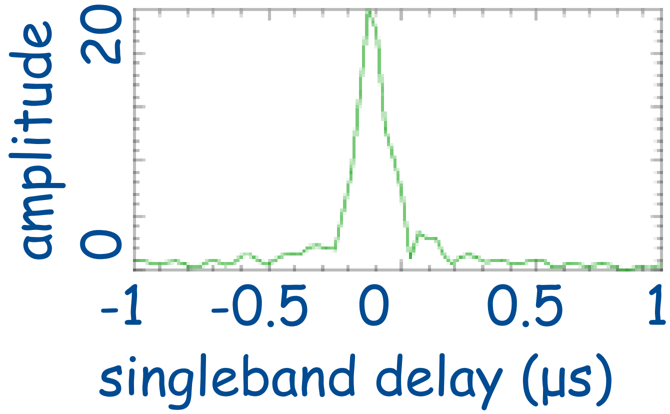
Causes:

- Often: wrongly calculated clock drifts.
- Seldom: wrong Earth orientation parameters (EOP).
- Rare: wrong sky frequency (not xxxx.99 MHz).
- Very rare: station position errors.
- Almost never seen: maser problem.

Cures?

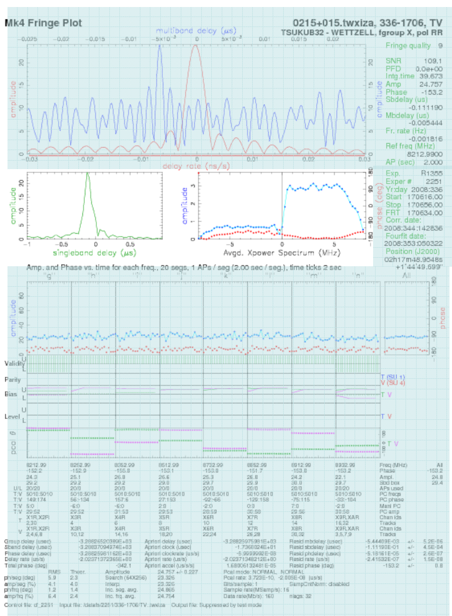
- Curable: wrongly calculated drifts, wrong EOP, station positions.
- Not curable but still valid: wrong sky frequency.

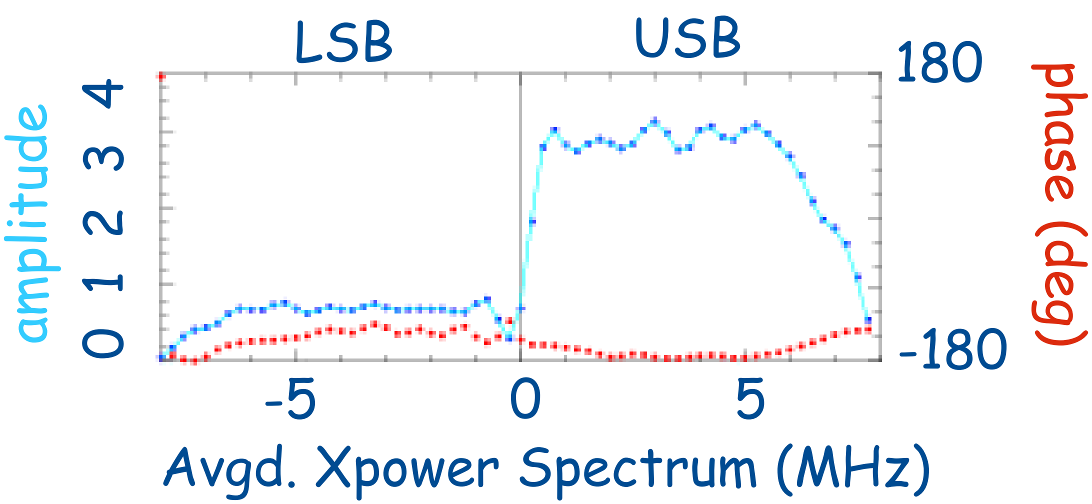
Fringe Fit: from Lag to Frequency



Fourier Transform

$$V(u,v,\tau) = \int V(u,v,\nu) e^{2\pi i \tau \nu} d\nu$$





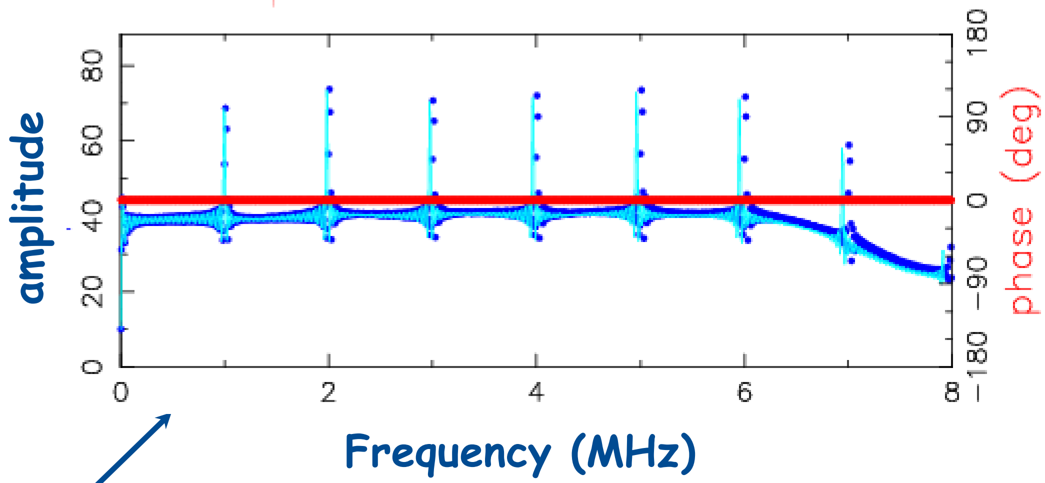
The data are already fringe fitted.

Task 14: Change the number of spectral channels in the v2d file: from nChan = 32 to nChan = 1024.

Run the correlation and look at the data with fourfit.

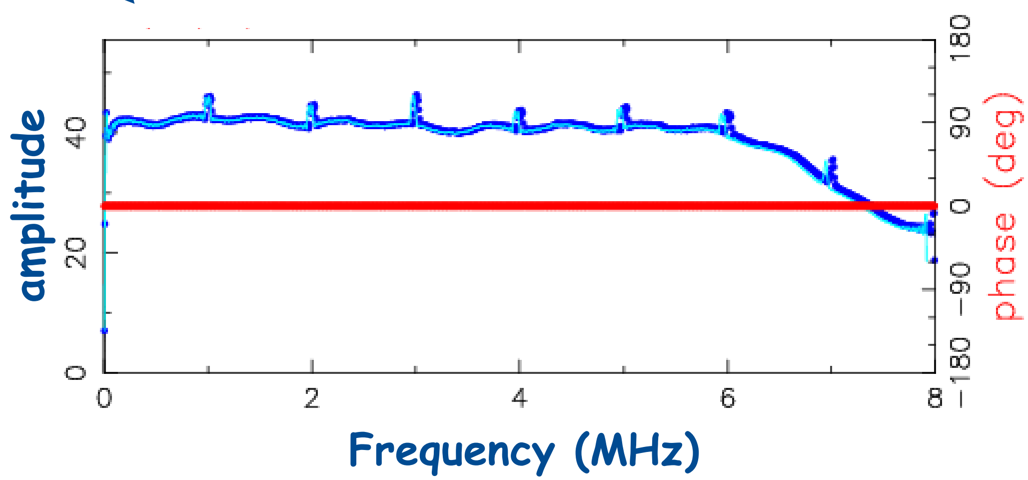
What happens?

Effects Visible in the Power Spectrum



The amplitude of the pcal tones is visible (enough power) at every MHz.

Autocorrelation plots (512 spectral channels)



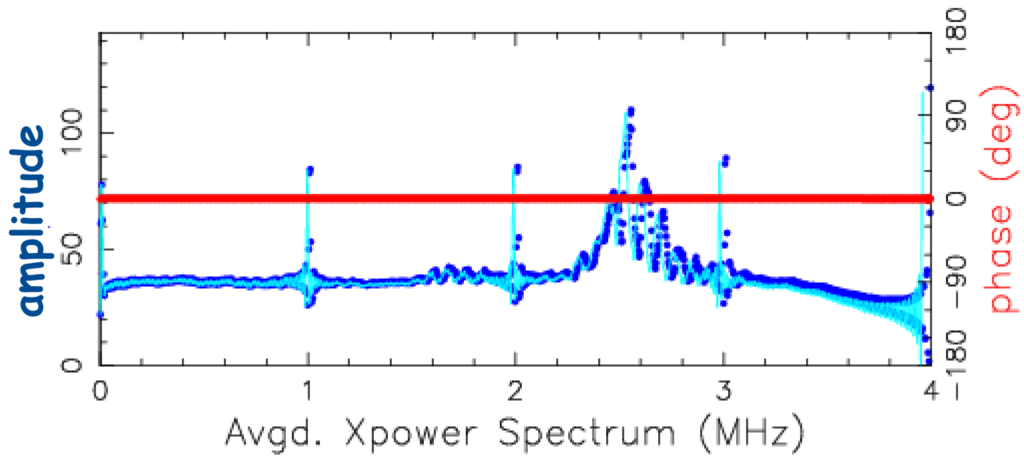
The amplitude of the pcal tones is too low (not enough power). Tones not usable for calibration.

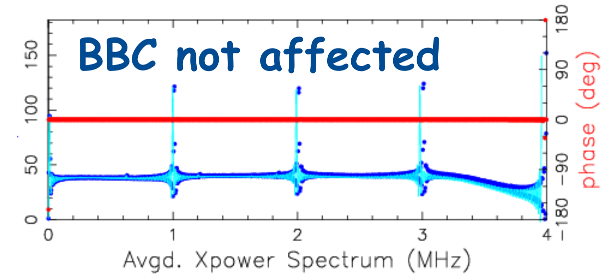
The correlator can be used as a very expensive spectrum analyzer: the power spectrum is a measure of the correlated filter responses at the two stations.

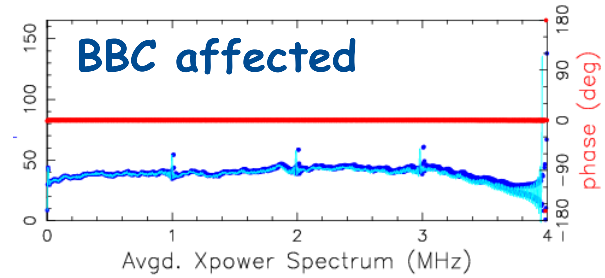
We see:

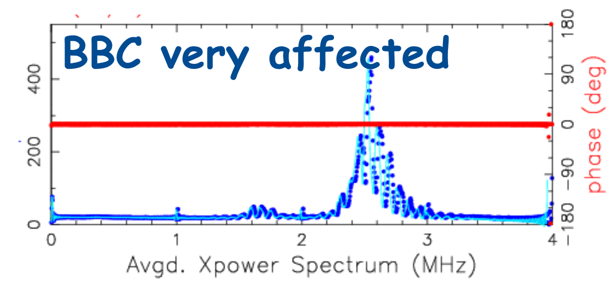
- Pcal tones (should be there!)
- RFI (should not be there!)
- USB/LSB offsets (to be removed when stations using two different DAR are cross-correlated. E.g. Mk4/VLBA).

Effects Visible in the Power Spectrum: RFI







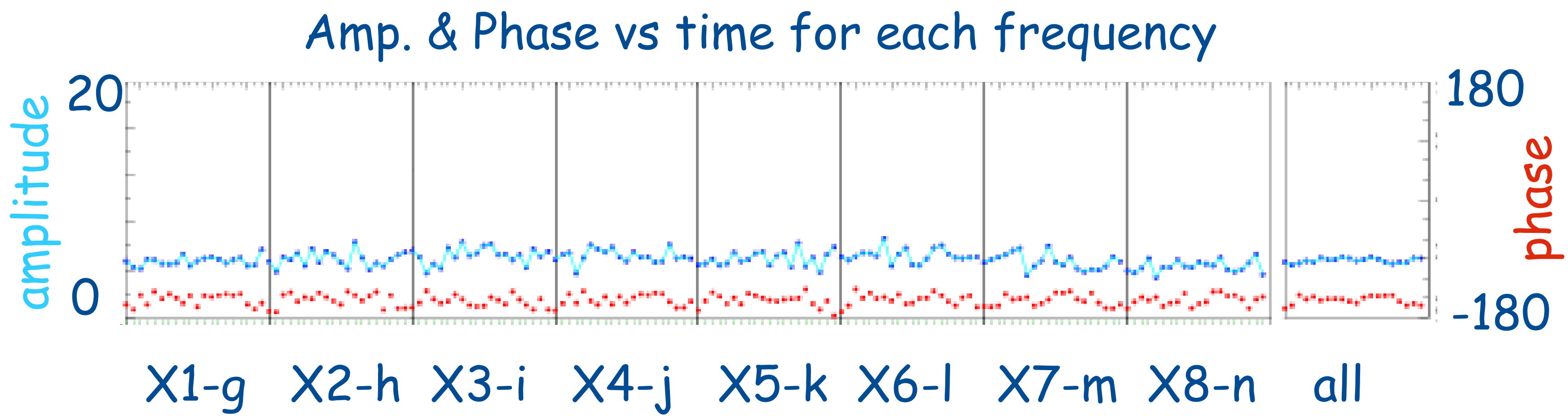


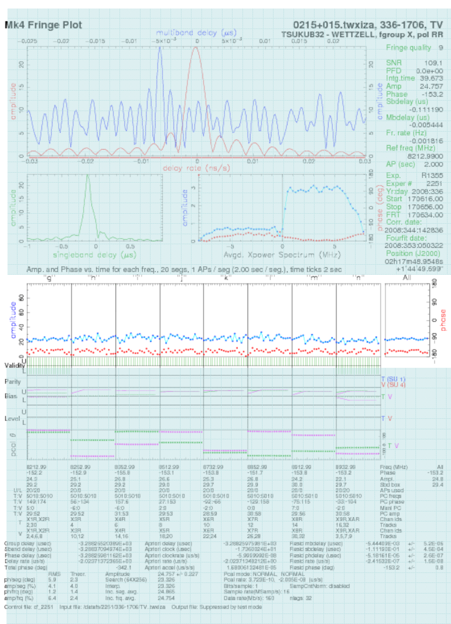
Very external RFI (mostly satellites at S-Band).

The signals are broadband => affect more than one BBC/VC channel.

Corrupt the visibility and pcal amplitude.

Cure: flag the affected channels.





- Every dot represents the phase (red) and amplitude (blue) of the visibility for every segment (~ AP).
- Data are already fringe fitted and pcal has been applied.
- Every BBC/VC channel is represented.

Amplitude & Phase vs time: Visible Effects

- RFI.
- BBC/VC specific problem (unlock, wrong sky freq…).
- LO instabilities (loss of coherence).
- IF problems (e.g. mixer setup "in" or "out").
- Low/absent pcal phase signal.
- Pointing (if one scan is compared with an old scan on the same source observed at the same sidereal time = same elevation).
- Source structure (bad news, geodesy likes pointlike sources).
- Atmosphere (ionosphere & troposphere).

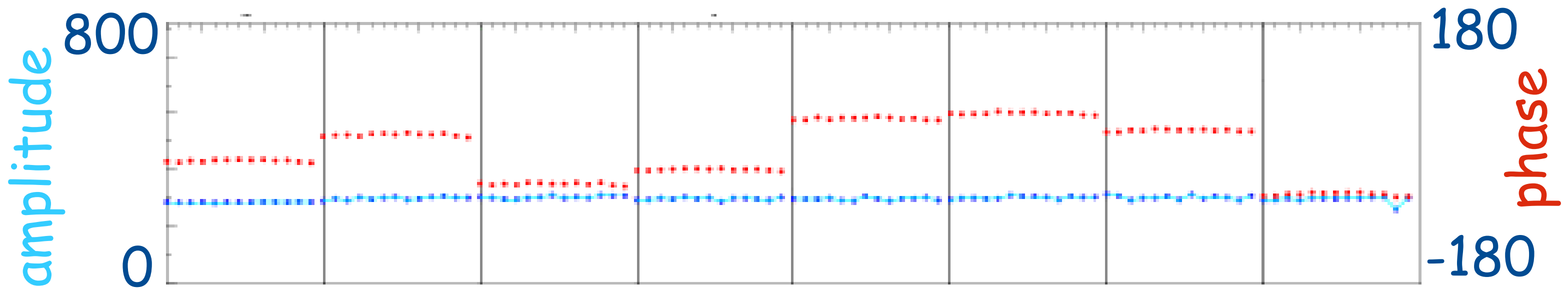
Task 15: Look at the S-band data with fourfit.

Do you recognize some of the mentioned effects?

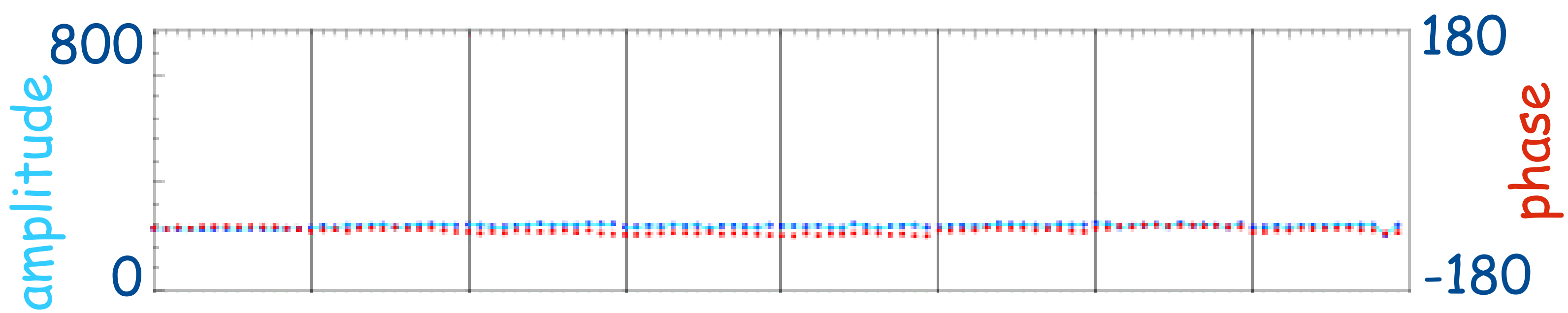
Fringe Fit: Phase Cal Phase

Corrects phase offset of each BBC/VC.

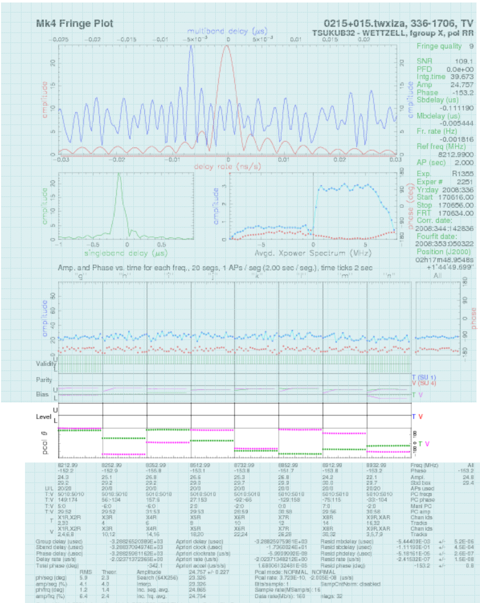
Phase offsets within the BBCs/VCs still present.



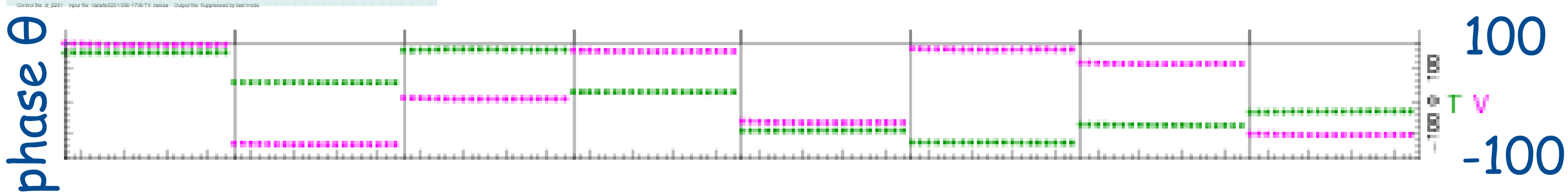
Phase cal phase flattens the phases across the band.



Fringe Fit:Phase Cal Phase Plot



- Phase cal phase are plotted whilst only the value of the mean coherent pcal amplitude (PC amp.) is written for each channel.



Reference Station ....
Remote Station ....

If pcal amp is too low => H-code => pcal unusable although pcal phase might be perfectly ok!!!

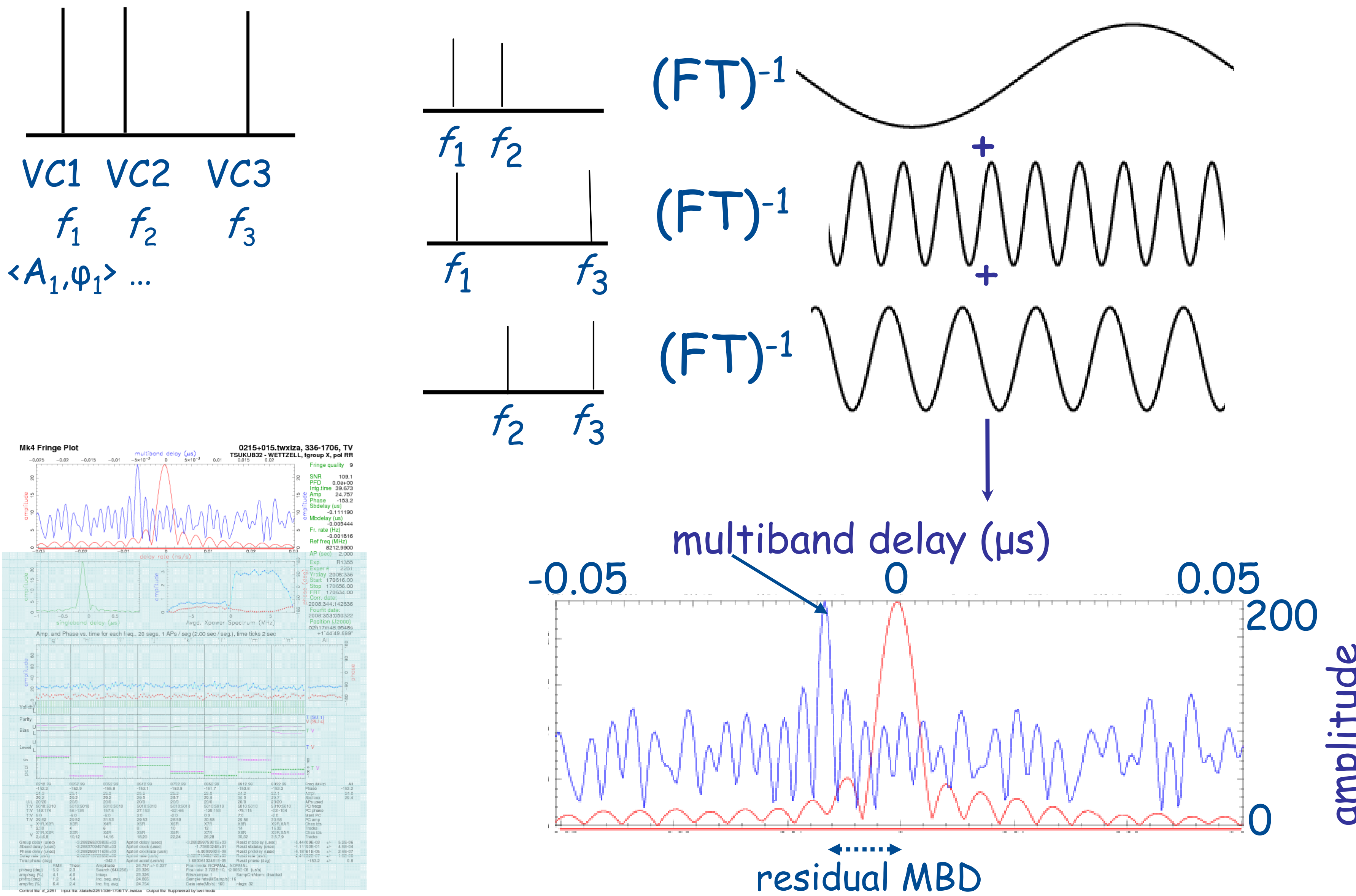
Multiband Delay (MBD)

To improve the delay resolution, the observations sample a small part of a wider band (e.g. 720 MHz) and the MBD is calculated as if the whole band were observed.

After delay and delay rate have been corrected and pcal are applied, fourfit calculated the MBD. Fourfit averages the visibilities in frequency, yielding one value of phase and amplitude per BBC per accumulation period (tInt).

Fourfit performs an inverse FFT (from frequency difference – time domain into -> MBD – delay rate domain). The MBD spectrum is formed as sums of the resulting sinusoids. The location of the peak gives the residual MBD soltution.

Multiband Delay



<u>Task 16</u>: Try to eliminate BBC channels from the fourfit plot.

How does the MBD function change?

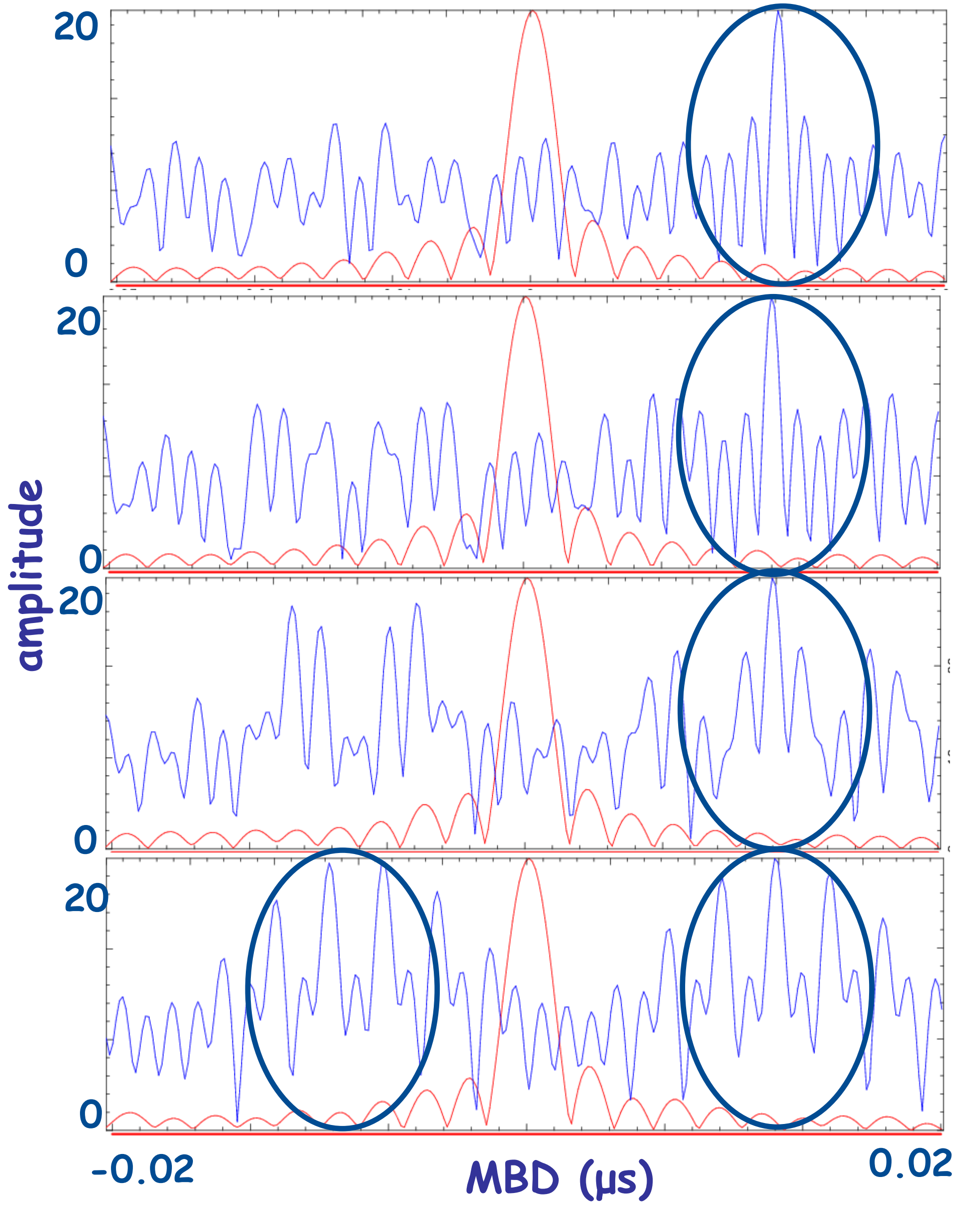
The command to use is:

```
fourfit -pt -c cf_1234 <scan> set freqs g h i j k l m n
```

i.e. fourfit -pt -c cf_1234 022-1700 set freqs g h j k l m

fourfit -pt -c cf_1234 022-1700 set freqs h k l m ....

Multiband Delay



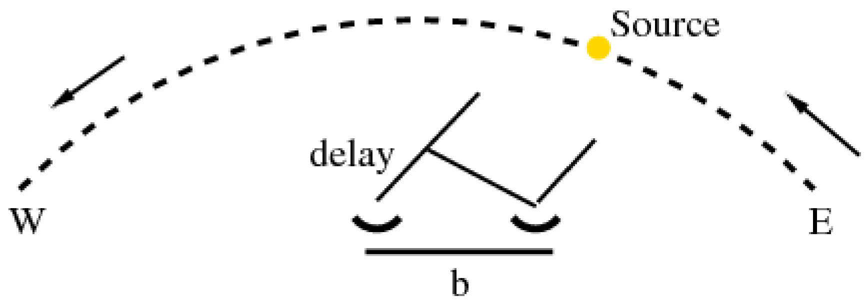
All BBCs: the MBD peak is clearly distinguishable from the side lobes.

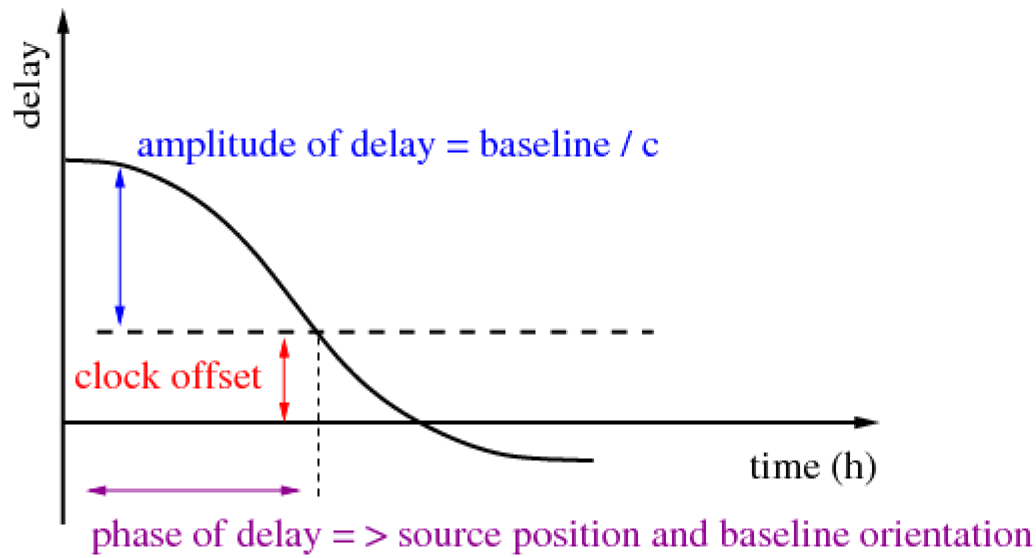
BBC06 removed: MBD very similar as above.

BBC04, BBC06 and BBC08 removed: the sidelobes grow, ambiguities still out of the window.

BBC03, BBC05, BBC07 and BBC08 removed: MBD peak hardly seen.

VLBI: Geodesy





Data Check also at the Station

Copy raw data (~ 3 MB) onto file and check the data with linux command *od*:

`od -tx4` file name

output is like:

frame no.

time stamp:MJD & second of day

fractional second & header error check

```
0000000 abaddeed bead0001 0974ad5f f00abf01
0000016 0d645d49 57143f17 3a19c152 a0ec5b58
```

`od` byte no. in file

data

...

ABADDEED => header sync word (every 10016 bytes)

if lots of hex are zeroes -> no input to DBBC

Other Tools to Check Data

Use `mark5access` library (part of DiFX, but should be possible to install them as stand-alone):

`m5d`: decode data (valid for all data kinds that DiFX reads).

`m5test`: decode data headers and data (valid for all data kinds that DiFX reads).

`m5bstate`: state counts summary (valid for all data kinds that DiFX reads).

`m5spec`: forms total power for each baseband channel in the file (never used by us!).

Other Tools to Check Data

```
m5d /path/file.m5b Mark5B-256-16-1 10   ➔
Mark5 stream: 0x89e130
stream = File-1/1=/data10/r1/nyalesund/r1538_ny_171-1212a
format = Mark5B-256-16-1 = 2
start mjd/sec = 97 43922.000000000
frame duration = 312500.00 ns
framenum = 0
sample rate = 16000000 Hz
offset = 0
framebytes = 10016 bytes
datasize = 10000 bytes
sample granularity = 1
frame granularity = 1
gframens = 312500
payload offset = 16
read position = 0
data window size = 1048576 bytes
-1   1   1   1  -1   1  -1  -1  -1  -1   1  -1  -1  -1   1  -1
 […]
10 / 10 samples unpacked
```

Other Tools to Check Data

```
m5test /path/file.m5b Mark5B-256-16-1
Mark5 stream: 0x89e130
stream = File-1/1=/data10/r1/nyalesund/r1538_ny_171-1212a
format = Mark5B-256-16-1 = 2
start mjd/sec = 97 43922.000000000
frame duration = 312500.00 ns
framenum = 0
sample rate = 16000000 Hz
offset = 0
framebytes = 10016 bytes
datasize = 10000 bytes
sample granularity = 1
frame granularity = 1
gframens = 312500
payload offset = 16
read position = 0
data window size = 1048576 bytes
frame_num=2 mjd=97 sec=43922 ns=000625000.0 n_valid=2 n_invalid=0
 [..]
frame_num=335990 mjd=97 sec=44026 ns=996875000.0 n_valid=335990
1679990000 / 1679990000 samples unpacked
```

Other Tools to Check Data


```
m5bstate /path/file.m5b Mark5B-2048-16-2
```

Ch	--	-	+	++	--	-	+	++	gfact
0	3937	2332	14736	3995	15.7	9.3	58.9	16.0	1.10
1	3921	8576	8552	3951	15.7	34.3	34.2	15.8	1.10
2	3968	8521	8580	3931	15.9	34.1	34.3	15.7	1.10
3	3833	8597	8651	3919	15.3	34.4	34.6	15.7	1.12
4	3857	8573	8628	3942	15.4	34.3	34.5	15.8	1.11
5	3951	8559	8518	3972	15.8	34.2	34.1	15.9	1.10
6	3947	8642	8416	3995	15.8	34.6	33.7	16.0	1.10
7	3991	8543	8525	3941	16.0	34.2	34.1	15.8	1.10
8	3961	8656	8430	3953	15.8	34.6	33.7	15.8	1.10
9	3934	8582	8531	3953	15.7	34.3	34.1	15.8	1.10
10	3896	8651	8615	3838	15.6	34.6	34.5	15.4	1.12
11	3909	8764	8458	3869	15.6	35.1	33.8	15.5	1.11
12	3971	8613	8531	3885	15.9	34.5	34.1	15.5	1.11
13	3988	8561	8370	4081	16.0	34.2	33.5	16.3	1.09
14	3844	8580	8679	3897	15.4	34.3	34.7	15.6	1.12
15	4002	8445	8581	3972	16.0	33.8	34.3	15.9	1.09

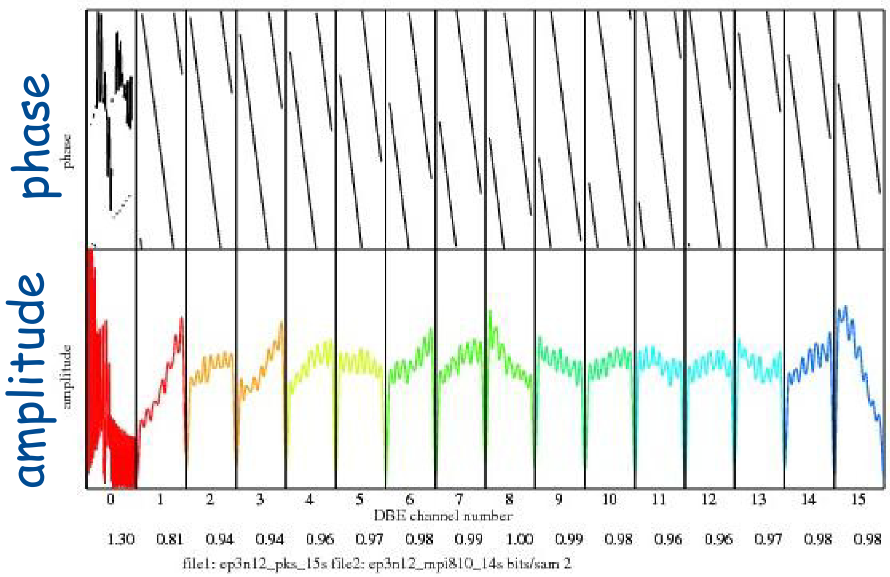
Other Tools to Check Data

Programs downloadable from Haystack:

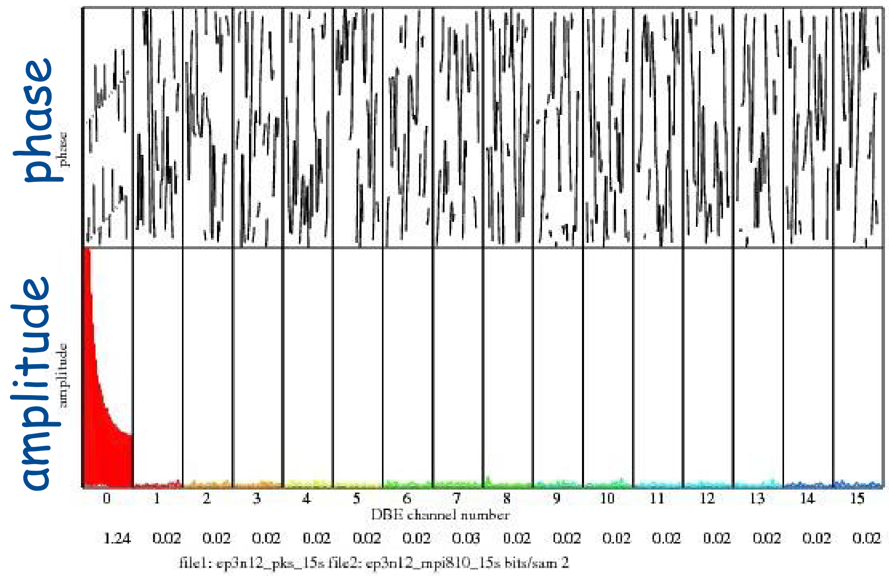
`vlbi2` only for 16-channels 2 bit sampling

`bstate` only for 16-channels 2 bit sampling

`vlbi0` only for DBE (or equivalent channel assignment)



Fringes



No fringes


Game Over ..
Try Again?